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Title: Verbal counting skill predicts later math performance and difficulties in middle school

Year: 2019

Version: Accepted version (Final draft)

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Please cite the original version:

Koponen, T., Aunola, K., & Nurmi, J.-E. (2019). Verbal counting skill predicts later math performance and difficulties in middle school. *Contemporary Educational Psychology*, 59, Article 101803. <https://doi.org/10.1016/j.cedpsych.2019.101803>

Verbal Counting Skill Predicts Later Math Performance and Difficulties in Middle School

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Abstract

This study examined the role of verbal counting skill as an early predictor of math performance and difficulties in middle school. The role of fourth-grade level arithmetical skills (i.e., calculation fluency, procedural calculation, and word problem solving) as mediators was also investigated. The participants included 207 children in central Finland who were studied from kindergarten to the seventh grade. Path modeling showed that verbal counting in kindergarten is a strong predictor for basic math performance in seventh grade, explaining even 52% of the variance in these skills after controlling for the mothers' education levels. This association between early verbal counting skill and basic math performance was partly mediated through fourth-grade procedural calculation and word problem solving skills. Furthermore, verbal counting had a direct effect on middle school math performance above and beyond the basic arithmetical and problem solving skills in fourth grade. Poor kindergarten verbal counting skill was a significant indicator for later difficulties in mathematics.

Keywords: Verbal counting, math, learning difficulties, longitudinal research

1. Verbal Counting Predicts Later Math Performance and Difficulties

Math learning disabilities are a major issue within the field of education, as they can have a serious negative impact on school achievement, increase the risk of poor educational engagement, and reduce employment opportunities and progress in jobs (Parsons & Bynner, 1997; Siegler, 2012). Previous research has demonstrated that math skills cumulate across school years: those with initially high skills show faster development, whereas those with initially poor skills show slower development and thus continuously lag behind (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). Consequently, finding user-friendly ways to identify learning difficulties early enough can be considered a worthwhile aim to improve mathematics education.

Previous research on math performance has provided important knowledge on the core number skills (e.g., verbal counting, enumeration, magnitude comparison, number concept, etc.) associated with school-aged math skills (Chen & Li, 2014; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Koponen et al., 2016; Schneider et al., 2016). However, existing longitudinal studies have mainly examined the predictive value of early number skills on primary school mathematics (e.g., Koponen, Salmi, Eklund, & Aro, 2013; Krajewski & Schneider, 2009; Nguyen et al., 2016), math skills within primary school (e.g., Fuchs, Geary, Fuchs, Compton, & Hamlett, 2016), or the predictive value of primary school mathematics on later math achievement in middle school or later (Duncan et al., 2007; Geary, Hoard, Nugent, & Bailey, 2013; Rabiner et al., 2016; Siegler et al., 2012). Based on these previous studies, little is known of the long-term predictive value of early number skills and how they work as early indicators for later math difficulties. Only one study has examined the extent to which preschool math ability and growth predicts math achievement after primary school (Watts, Duncan, Siegler, & Davis-Kean, 2014).

The present study focused on the verbal counting skill (i.e., ability to recite number words in correct order forward and backward from a given number), which has been shown to be among the best predictors of the level and growth of arithmetical skills in primary school (Aunola, Leskinen et al., 2004; Koponen, Aunola, Ahonen, & Nurmi, 2007, 2013, 2016; Zhang et al., 2014). In particular, we were interested in whether verbal counting has long-term predictive power on math performance in middle school and whether that predictive power is mediated via arithmetical skills in elementary school or the existence of a direct predictive path as well. Moreover, we were keen to discover to what extent we can identify the children during entrance to kindergarten—before formal instruction and systematic introduction to written numbers—who are at risk for struggling in math persistently and showing difficulties later at school. To our knowledge, no previous studies have examined the effects of early number skills as long-term risk indicators.

1.1. Early Number Skills and Their Development

Before entering school, young children typically show an understanding of important early number skills, such as the concept of numbers (child can give five candies); verbal counting, that is, reciting number words in the correct sequence (“one, two three . . .”) and using this sequence in enumeration (counting objects); and comparing the numerical magnitude of separate sets (** vs. * or 3 vs. 2). These early number skills form a foundation for learning basic arithmetical skills during their first years in school (Koponen et al., 2016; Krajewski & Schneider, 2009). Understanding the hierarchy of early number skills is also important from a practical standpoint, providing crucial information on why some children do not respond to instruction in school and forming guidelines for giving the appropriate support. According to a model created by Krajewski (2008), early quantity-number competencies are acquired in three phases, leading children toward a deeper understanding of quantity to number-word linkage. In the first phase (Level I), number-word

sequences are isolated from quantities (basic numerical skills), and verbal counting is not yet used as a tool for enumeration. In the second phase of development (Level II), number words are linked with quantity (e.g., ***** = five). Finally, in the third phase (Level III), children begin to understand the relationship between quantities and linking quantity relations with numbers (e.g., 2 and 3 makes 5; 5 is 2 larger than 3).

1.2. Early Number Skills as Predictors of Later Math Performance

The sooner the reliable predictors for math skill development can be identified, the earlier targeted support for children at risk of developing learning difficulties can be provided. A majority of recent studies examining the core predictors of later math performance have focused on magnitude comparison, which reflects an ability to discriminate and compare numerical quantities (Ansari, 2008). Magnitude comparison is typically assessed by presenting two sets of stimuli (e.g., two dot arrays, sequences of sounds or numbers) and asking the participant to select the more numerous. A recent meta-analysis integrated the finding across studies and examined the strength of the association of symbolic (3 vs. 2) and nonsymbolic (** vs. *) magnitude comparison with different math competences. Magnitude comparison was shown to correlate with mental and written arithmetical correlations varying from .28 to .38 (Schneider et al., 2016). Moreover, it was shown that symbolic magnitude comparison with numbers is a stronger predictor for later math learning in school compared to nonsymbolic magnitude comparison with quantities (Schneider et al., 2016). From a practical point of view, a clear limitation is that the outcome variable in magnitude comparison tasks has typically been reaction time, solution rate, or Weber fraction (smallest ratio of two numerosities that a person can reliably detect as larger or smaller), which are not simple to apply or assess in practical life among young children, thus lack ecological value as an identification tool. Reliability in the kindergarten context is also questionable because all of these outcome variables require exact time measuring.

However, recent findings suggest that other powerful predictors should be taken into account as well. Several studies (e.g., Aunola et al., 2004; Koponen et al., 2016; Krawjeski et al., 2009; Zhang et al., 2014) have shown verbal counting to be a strong predictor for level and growth of arithmetical skills in primary school. In these studies, correlations between counting and later arithmetical calculation have varied from .32 to .53, which is high even when compared to other core number skills, such as magnitude comparison. However, as with other early number skills, long-term predictive power has not been examined. Thus, it is not clear whether predictive power can extend to math performance after elementary school and, especially, whether it has any predictive power above and beyond arithmetical skills in elementary school. Verbal counting can be assessed rather easily in the natural settings of kindergarten classes or day-care centers by teachers, providing good ecological value. However, the value of verbal counting as an early identification tool should be examined, which sets, next to the aims of examining the direct and indirect (via 4th grade arithmetic) predictive effects of verbal counting on math performance in middle school, the third aim for the present study.

The only study (i.e., Watts et al., 2014) examining long-term predictive effects of early number skills in preschool on middle school math performance explored applied problem solving skills. Watts et al. found that applied problem solving in kindergarten and growth from preschool to first grade were significant predictors for math achievement in middle school. However, the study did not examine whether applied problem solving in preschool had a unique predictive effect on math performance in middle school above and beyond basic math skills in elementary school or whether it was a predictive effect mediated via basic math skills in elementary school. To clarify the developmental mechanism, it is important to examine the role of primary school math as a mediating factor when using early number skills as predictors for math performance in middle school. To our knowledge, no

previous studies have examined the extent to which the predictive effect of early number skills on math skills in middle school is mediated by basic arithmetical and problem solving in primary school. Analyzing the direct and indirect predictive paths for early number skills can also help sharpen theoretical knowledge concerning the hierarchical structure of math skills.

Moreover, from a practical point of view, an applied problem solving task might not be a simple tool to use. There are several ways to operationalize an applied problem solving skill, which can hamper its use as a practical tool for identification and providing information for preventive support. In the present study, the aim was to examine the predictive effect of a simple early number skill, verbal counting. The main reasons for selecting verbal counting were that it is possible to assess rather easily in natural settings in kindergarten or day-care centers, no expensive test materials are required, and verbal counting has already been shown to have strong predictive power on math proficiency in primary school.

1.3. Verbal Counting as an Early Predictor for Math Performance

In mathematics, a central goal for the first few years of instruction is to achieve an effortless and fluent arithmetical calculation skill as a tool for continued learning. The subsequent acquisition of mathematics is severely compromised if basic arithmetical calculation skills are poor. Developmentally speaking, the learning of calculation is gradual. Children first learn calculation strategies based on counting to solve simple arithmetical problems (Ostad, 1999; Siegler & Shrager, 1984). Fingers (or other countable objects) are counted one by one to form an addend, and this process is then repeated with another addend (Baroody, 1987). These strategies, initially relying on manipulatives, become rapidly internalized as verbal counting skills. During this development, children learn to begin counting from the first addend (e.g., $2 + 5, \dots 3, 4, 5, 6, 7$) and later from the larger addends (e.g., $2 + 5, \dots 6, 7$). There is an assumption that frequent and successful use of counting

strategies increases memory representations for arithmetical facts and leads to a strategy for their retrieval from long-term memory (Barrouillet & Fayol, 1998; Siegler & Shrager, 1984).

Regarding age-appropriate development of arithmetical skill, children typically begin using fact retrieval as the main strategy for solving calculation problems around the age of 9 (Brauwer, Verguts, & Fias, 2006; Lemair & Siegler, 1995). An inability to store and/or retrieve arithmetical facts is the most typical feature of math learning disabilities that cause disfluency (Geary, 1993; Landerl et al., 2004). A fluent and accurate counting procedure is important to the formation of long-term memory associations between the presented problem and the answer. This also facilitates the shift from counting-based strategies to the faster calculation strategy of fact retrieval. Moreover, a recent study (i.e., Uittenhove, Thevenot, & Barrouillet, 2016) of adults emphasized that in rapid arithmetical calculation processes with small addition problems, adults use an automatized counting procedure. The findings suggest that very fast responses, mistakenly interpreted as direct retrieval of the answer from memory, actually subsume compiled and automated procedures that are faster than fact retrieval and deliver the answer while the subject remains unaware of the process. This is a theoretical claim, and reverse misinterpretation might occur as well when retrieving arithmetical facts from memory. However, it could explain at least partially why verbal counting abilities measured before entering school have been found to predict arithmetical calculation skills up to at least fourth grade among a typical sample of children (Aunola et al., 2004; Koponen, et al., 2007; Krajewski & Schneider, 2009). Verbal counting abilities are also strongly related to calculation skills among children with language impairments (Donlan, Cowan, Newton, & Lloyd, 2007) where the use of counting-based strategies is common also among older children due to difficulties in arithmetical fact retrieval. Despite the importance of early verbal counting skills as predictors for basic arithmetical skills in primary school, no previous studies have examined whether the predictive power of verbal counting skills

extends to the upper level of comprehensive (middle) school, that is, above and beyond basic arithmetical skills. Moreover, no previous studies have explored the value of verbal counting skills as indicators for the risk of developing later math difficulties. However, this information is very important for schools because finding tools that can be used for the early identification of children at risk for long-term persistent difficulties in math enables schools to provide preventive support.

Verbal counting skills emerge from and are developed through individual learning and cultural transmission. Regarding background factors, the parents' educational levels have been shown to be related to verbal counting and later arithmetical skills in children (Koponen et al., 2007). Parents' learning experiences during their own schooling have been suggested as influential on how they interact with their children during learning activities at home (for a review, see Eccles, 2005). Education could influence parents' skills, values and beliefs, knowledge of educational systems, and methods of educational practice at home. Thus, in the present study, the mother's education level was taken into account while examining the long-term predictive value of counting skills.

1.4. Research Questions

The present study addressed three research questions. First, to what extent do verbal counting skills at the beginning of kindergarten predict math performance in seventh grade (Model 1)? Previous studies examining the effect of verbal counting skills, measured in kindergarten, on the development of math skills during the first years of schooling (e.g., Aunola et al., 2004) or fourth-grade arithmetical skills (e.g., Koponen et al., 2007) have shown a strong relation between these skills. Based on the findings from these studies, the researchers of the present study assumed that verbal counting abilities also predict math performance in seventh grade.

Second, to what extent is the predictive relation of verbal counting and math performance in seventh grade mediated via arithmetical skills (e.g., calculation fluency and written calculation with multi-digit numbers) and word problem solving skills in fourth grade (Model 2)? Because earlier studies (Aunola et al., 2004; Koponen et al., 2016) have reported a strong relationship between verbal counting and arithmetical, it is expected that arithmetical skills (e.g., fluency of single-digit calculation and arithmetical calculation) mediate the impact of verbal counting skills on subsequent math achievement in seventh grade.

Third, how large is the proportion of children who experience difficulties in seventh-grade mathematics (i.e., those performing below -1.5 standard deviation [SD]) who also had poor performances in verbal counting skills at the beginning of kindergarten?

2. Methodology

2.1. Participants and Procedures

This study is a part of the Jyväskylä Entrance into Primary School (JEPS) study by Nurmi and Aunola (1999–2009). The aim of JEPS is to investigate the development of a broad range of cognitive, social, and motivational factors among children from kindergarten to primary school. The original sample of 207 participants (5 or 6 years of age at baseline, $M = 75$ months, $SD = 3.3$) comprised an entire age cohort from the two medium-sized communities, including both suburban and rural areas (with populations of 5,019 and 8,407, respectively), in central Finland. The sample was homogeneous in terms of race and cultural background, as is typical in Finnish schools. The participants were all native Finnish speakers with no documented intellectual or sensory deficits. Parental permission to gather data from the children was obtained at the beginning of the study and again when the children reached fourth grade and seventh grade. As the study progressed, 36 children dropped out of the study or moved away; thus, the sample of seventh-grade children included 171 of the original sample. Data gathered from three assessment points were used in the present study, including

the beginning of kindergarten, the end of fourth grade, and the end of seventh grade. Attrition analyses showed no differences in the predictive variables (i.e., verbal counting or mother's education level) between children with full data sets and those without. Formal education in Finland starts with primary school (first grade). Children enter primary school during the year they turn 7. The formal education of primary school mathematics follows a curriculum provided by the Finnish Ministry of Education, which is the same for all children. In Finnish kindergarten, there is no formal instruction in mathematics or reading, but play-centered activities support the development of number and language skills.

The mothers were sent a questionnaire during the fall term of their child's year in kindergarten. They returned the questionnaire directly to the researchers by mail, and the response rate was 92.3%. Although the fathers were also sent a questionnaire, in the present study the information on the mothers' educational level was used rather than fathers' educational level. The reason for this was that the response rate of mothers was higher than that of fathers (response rate 77.7%) and, thus, the variable for mothers' education was considered to be more representative than that for fathers. A total of 18% of mothers had a master's degree or higher, 44% had a bachelor's degree or vocational college degree, 24% had a vocational school degree, and 14% had no education beyond comprehensive (middle) school.

2.2. Measurements

Math skills were assessed in three different phases. Verbal counting skill was assessed at the beginning of kindergarten, arithmetical skills (calculation fluency, procedural calculation, and word problems) at the end of fourth grade, and math performance at the end of seventh grade.

2.2.1. Verbal counting (kindergarten). Children's verbal counting abilities (reciting number words forward or backward) were measured at the beginning of kindergarten using

parts of the test array provided in Diagnostic Test 3: Motivation, Metacognition, and Mathematics (Salonen et al., 1994). This test consists of three subtests. In the first subtest, children were given a starting number and asked to count forward. One point was awarded if the child was able to correctly count forward to at least four numbers. This subtest consisted of four trials with different starting numbers for each trial (i.e., 3, 8, 12, and 19). In the second subtest, children were given a starting number and asked to count backward. One point was awarded if the child was able to correctly count backward to at least four numbers. This subtest also consisted of four trials with different starting numbers for each trial (i.e., 4, 8, 12, and 23). In the final subtest, children were asked four questions designed to assess their knowledge of the ordinal aspects of numbers (e.g., “What is the number you get when you count five numbers forward from two?”). One point was awarded for each correct answer. Cronbach’s alpha (α) reliability score for the verbal counting test was .79. Coefficient H (Hancock & Mueller, 2001) for the latent verbal counting was .85.

Difficulties in verbal counting. To form a variable representing difficulties in kindergarten-level counting, children were classified into three categories according to their verbal counting skills:

- no difficulties (ND: above -1 *SD*),
- low verbal counting skills (LS: at or below -1 *SD* but above -1.5 *SD*; i.e., moderate level of difficulty), and
- poor verbal counting skills (PS: at or below -1.5 *SD*; i.e., clear or more severe difficulty).

In the present study, a performance value with a *SD* 1.5 below average was used as the cutoff criterion when defining difficulties in mathematics, which is comparable to the prevalence rates previously reported for math difficulties (Butterworth, 2008).

2.2.2. Calculation fluency (fourth grade). Calculation fluency was assessed using two tasks. In the first task, the children were presented with 120 single-digit addition problems using permutations from 1 to 9. The exam consisted of an instruction page with examples of the task and three test pages with 40 problems on each page. The problems were arranged in a quasi-random order such that each successive item had a different addend. Children were instructed to write in their answer as quickly as possible, calculating as many problems as they could in a 3-minute time limit. A stopwatch was used to measure the time taken. In the second task, 120 single-digit multiplication problems were presented to children in the same manner as the first task, with the same 3-minute time limit. The mean accuracies (i.e., correct answers divided by total number of problems answered) from the addition and multiplication tasks were very high (98% and 97%, respectively), meaning that variance within this variable is mainly caused by calculation fluency. The mean scores from both tasks were used as a variable for single-digit calculation. Cronbach's α reliability score for this test was .88.

2.2.3. Procedural calculation (fourth grade). Procedural calculation was assessed by presenting the children with six horizontal, multi-digit addition problems (e.g., $527 + 31 = ?$; $1635 + 576 = ?$), six multi-digit subtraction problems (e.g., $485 - 42 = ?$; $2356 - 867 = ?$), four multiplication problems (e.g., $4 \times 700 = ?$; $12 \times 28 = ?$), four division problems (e.g., $240 \div 80 = ?$; $363 \div 11 = ?$), and eight problems that combined these arithmetical operations (e.g., $104 + 22 - 7 = ?$; $3 \times 7 + 12 = ?$; $40 \div 8 - 3 = ?$). Regrouping was required in 12 of the 28 problems. Children were asked to complete as many of the problems as they could. They were allowed to align numbers vertically and write on the paper as they solved. One point was given for each correct answer. A sum score for procedural calculation was computed by adding up the correct answers. Cronbach's α reliability score for this test was .86.

2.2.4. Word problems (fourth grade). Skills for solving math word problems were assessed using a subtest that consisted of word problem solving from the NMART test array (Koponen & Räsänen, 2003). The subtest consisted of 20 word problems that covered all four arithmetical operations—addition, subtraction, multiplication, and division—as well as their combinations (e.g., *A book costs 6 euros, and a comic book costs 4 euros. Pekka bought three books and five comic books. How much would he get back from 50 euros?*). One point was given for each correct answer, with a maximum score of 20. Cronbach's α reliability score for the whole scale of tests was .80.

2.2.5. Math performance (seventh grade). Seventh-grade math performance was measured using the Test for Basic Math Skills for Grades 7–9 (KTLT; Räsänen & Leino, 2005). The test contains items from different core areas of mathematics, including arithmetical and algebraic items, both as symbols (e.g., “ $5.01 + 6.7 = ?$ ”) and as word problems. The test requires a knowledge of whole numbers as well as fractions and decimals. There are also equations (e.g., “Calculate $-3x$ when $x = 3$ ”) and geometry problems. The test has four parallel versions (A, B, C, and D). Version A was used in this study. Each test version contains 40 calculation tasks that must be completed within 40 minutes. The maximum score is 40. The internal reliability of test version A using normative data ($N = 1157$) was .88 (Räsänen & Leino, 2005).

Math learning difficulties (seventh grade). To measure the variable representing math learning difficulties in seventh grade, children were classified into three categories according to their seventh-grade math performance scores:

- no difficulties (ND: above -1 SD),
- low math performance (LS: at or below -1 SD but above -1.5 SD; i.e., moderate level of difficulty), and

- poor math performance (PS: at or below -1.5 SD; i.e., clear or more severe difficulty).

2.2.6. Mother's education. To determine their level of education, mothers were asked about their educational background on a 4-point scale (1 = *junior high school level of education*, 2 = *junior high school and trade school education*, 3 = *a college of professional education [e.g., business and administration]*, 4 = *a degree from an institution of university standing*).

2.3. Data Analysis

To answer the first two research questions, structural equation modeling (SEM) was used. In the modelling, latent factor for verbal counting was created from three subscales, that is, counting on forward, counting on backward, and counting forward certain steps. The first model measured the direct path from verbal counting to subsequent math performance in seventh grade, after controlling for the mothers' education levels. In this model, the latent construct for verbal counting consisted of three observed variables (i.e., counting forward from a given number, counting backward from a given number, and counting forward within a given range).

In the second model, three arithmetical subskills (i.e., calculation fluency, procedural calculation, and word problem solving), assessed at the fourth-grade level, were added to the previous model. The direct path from early verbal counting skills to seventh-grade math performance and the indirect paths were estimated via the three arithmetical subskills. This model was further elaborated on by removing all nonsignificant paths one by one, starting with the least-significant path.

Data analyses were carried out using the Mplus 7.4 program (Muthén & Muthén, 1988–2015). The model parameters were estimated using the MLR procedure. The goodness-

of-fit of the estimated model was evaluated using five indicators: an χ^2 test, the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR).

To answer the third research question (i.e., how large is the proportion of children who experience difficulties in seventh-grade mathematics who also had poor performances in verbal counting skills at the beginning of kindergarten?), cross-tabulated associations between variables in learning difficulty were analyzed using the chi-square test.

3. Results

3.1. Descriptive Statistics

The means and standard deviations of the sum variables are presented in Table 1, and their correlations are presented in Table 2. The correlation between verbal counting skills and math performance in seventh grade was .59 ($p < .001$). The correlations between verbal counting skills and fourth-grade calculation and problem solving skills varied between .50 and .59 ($p < .001$). The correlations between fourth-grade calculation and problem solving skills and math performance in seventh grade varied between .53 and .77 ($p < .001$).

3.2. Verbal Counting as a Predictor for Math Performance in Seventh Grade

The primary goal of the present study was to examine the extent to which counting skills, measured in kindergarten, could predict math performance in seventh grade, after controlling for the mothers' education levels. Model 1 investigated the extent to which seventh-grade math performance was predicted by early counting skills and included control for the mothers' education levels. In the model, latent factor for verbal counting was created from three subscales: counting on forward, counting on backward, and counting forward certain steps. The residuals of the counting on forward and counting on backward was allowed to correlate. The loadings of the latent factor 'Verbal counting' were rather equal varying from .62 to .72. The model fit indices were good (see Figure 1). The results showed

that after adding the mother's educational levels, early counting skills predicted for 52% of the variance in subsequent seventh-grade math performance.

3.3. Direct and Indirect Predictive Relations between Verbal Counting and Math Performance

The second aim of this study was to examine the extent to which the predictive relation between verbal counting skills and math performance in seventh grade is mediated via fourth-grade calculation fluency, arithmetical calculation, and word problem solving skills. Model 2 included kindergarten verbal counting skills; fourth-grade calculation fluency, arithmetical calculation, and word problem solving skills; and math performance in seventh grade, all of which fit the data well (see Figure 2). The results showed that verbal counting skills at the beginning of kindergarten, together with fourth-grade calculation fluency, procedural calculation, and word problem solving skills, predicted for 70% of the variance in seventh-grade math performance. Verbal counting skills were a positive and statistically significant predictor for all fourth-grade math skills. Of the fourth-grade math skills, procedural calculation and word problem solving skills were significant predictors for math performance in seventh grade. The results further implicated that verbal counting skills had indirect impacts on subsequent seventh-grade math performance via procedural calculation (standardized indirect estimate = .21, $p < .001$) and word problem solving (standardized indirect estimate = .25, $p < .001$), as well as a direct impact (standardized estimate = .25, $p < .01$).

3.4. Early Verbal Counting Skills as Risk Indicators for Later Math Difficulties in Middle School

Finally, we also examined whether difficulties in verbal counting are related to difficulties in math performance (i.e., performing below $-1.5 SD$) in seventh grade. The chi-square test revealed a significant dependency ($\chi^2(4) = 60.95, p < .001$) between difficulties in

kindergarten and in seventh grade (see Table 3). The adjusted residuals further indicated that children showing poor math performance (i.e., performing at or below $-1.5 SD$) in seventh grade made up a significant proportion of children who showed poor verbal counting skills in kindergarten.

Most of the children (i.e., 10 out of 13, or 77%) who showed poor math performance in seventh grade also had severe difficulties with verbal counting in kindergarten. Of the remaining poor performers, one child who performed poorly in seventh grade math had low performance in kindergarten verbal counting skills (i.e., at or below $-1 SD$, but above $-1.5 SD$), and only two children with poor performances in seventh grade performed in verbal counting at the level of their peers in kindergarten (i.e., above $-1 SD$). From another angle, 65% (13 out of 20) of children who performed poorly in verbal counting in kindergarten had poor or low math performances in seventh grade.

4. Discussion

This study examined the importance of verbal counting skills, measured at the beginning of kindergarten, for predicting math skills in middle school. The results showed that verbal counting is a strong predictor for basic math skills in seventh grade, explaining over 50% of skill variance after controlling for the mother's education.

This predictive relationship is partially mediated via fourth-grade arithmetical skills, particularly by procedural calculation and word problem solving skills. Interestingly, verbal counting skills also had a direct predictive effect on middle school math performance above and beyond basic, fourth-grade arithmetical skills. Moreover, difficulties in verbal counting skills were found to be a significant indicator for later difficulties in seventh-grade mathematics: most of the children experiencing severe difficulties in math at seventh grade (at or below $-1.5 SD$) had weak performance in verbal counting already at the beginning of kindergarten.

4.1. Counting as a Predictor for Math Performance

In line with the findings from previous studies (e.g., Aunola et al., 2004; Koponen et al., 2016; Koponen et al., 2007; Krajewski & Schneider, 2009; Zhang et al., 2014), the results of the present study revealed that verbal counting skill in kindergarten is a strong predictor for arithmetical skills in fourth grade, including both single-digit calculation fluency and procedural calculation fluency (i.e., multi-digit calculation with different operations) as well as word problem solving skills. Most importantly, verbal counting skills measured at the beginning of kindergarten (i.e., the autumn of the year a child turns 6) were found to have a strong, long-term predictive value for seventh-grade math performance. The correlation between counting in kindergarten and math performance in seventh grade was even stronger than that between counting and calculation fluency in fourth grade. Early counting skills had a direct predictive path toward math performance in seventh grade, even after the predictive pathways of fourth-grade calculation fluency, arithmetical calculation, and word problem solving were included in the models.

This strong, long-term predictive impact of early counting skills on middle school math skills is surprising given that verbal counting has been classified as a first-level quantity-number skill (Krawjeski, 2008). The findings of the present study support the view of strong stability in the development of math skills (e.g., Aunola et al., 2004). The results also suggest that verbal counting skills at the age of 5 are much more than just stringing words together or a tool for simple calculation. The early knowledge of numerical sequence reflects on the abilities that are necessary for learning more complex mathematics. The strong predictive power of verbal counting is a question that requires further studies. A recent study by Koponen and her colleagues (Koponen, Salmi, & Eklund, 2018) showed that, in contrast to the hypothesis created based on existing literature, a rather small part of the variance in verbal counting skill in the beginning of school was explained by language skills and

nonverbal reasoning at the age of 5. In another recent study (Authors, in revision), one-third of the variance in verbal counting fluency was explained by working memory, articulation speed, and processing speed, indicating a multicomponential nature. However, most of the variance was left unexplained in both of these studies, and domain-specific predictors were not included. In addition, learning sequential information (similar to learning the order of months, days, alphabets, etc.) verbal counting differs from other verbal sequences in one very meaningful way. Most of the verbal sequences have to be learned by heart; there are no rules to discover, such as in counting sequence where number words for 10 and smaller will be used to compose larger number words using rules. Learning to count in many languages, including Finnish, means acquiring arbitrary sequences of number words below 10, as well as the knowledge of the syntax and grammar for the structure of higher numbers (Fuson, 1988). In different languages, the structure of number words varies according to how transparent the number word system is with a 10-base system. In Chinese, number words are fully transparent, and 11 and larger number words follow the logic of the 10-base system (*ten and one, ten and two*, etc.). In the Finnish language, this transparency starts after 20 and, in that sense, is more similar to English. Thus, learning number sequences is not purely about associative learning but discovering the rules and logic of the number system. The present study suggests that difficulties in learning and producing number sequences, that is, in verbal counting, can have a long-term influence and reflect a deficit in the ability needed for learning math knowledge. In agreement with this suggestion, training in structuring numbers has been found to be beneficial in learning arithmetic (e.g., Ellemor-Collins & Wright, 2009).

4.2. Counting Difficulties as a Risk Indicator for Later Learning Difficulties

No previous studies have examined the role of early counting skills as a risk indicator for later math learning difficulties. The results of the present study show that, in most cases, poor performance in seventh-grade mathematics is preceded by poor or low verbal counting

skill in kindergarten, starting from the age of 5 or 6. This is an important finding that has clear and practical implications for mathematics education. The researchers argue that verbal counting skills work as important indicators for core math knowledge and have strong predictive value for later math learning. Thus, the measurement of verbal counting skills in kindergarten can be an important tool for detecting at-risk children in need of early support, as well as monitoring math skill development. Verbal counting skill is easy to assess and should be included in the test arrays already used to assess school readiness. The earlier schools can identify children at risk for developing difficulties in math skills, the earlier targeted support can be provided. Of course, there is still a lack of knowledge as to what extent practicing the verbal counting skill (i.e., verbal rehearsal) can decrease the risk for developing learning difficulties. To answer this question, further interventional studies are needed.

4.3. Limitations

The present study has some limitations and suggestion for further research. Based on the previous literature, which has both shown the strong predictive power of verbal counting skill on primary school math and lacked the empirical evidence related to the long-term predictive value of counting, the present study focused on examining whether the predictive value of counting skills continues to middle school.

Using verbal counting as a single predictor also has limitations. It is assumed that early in development, verbal counting skills develop independently from the innate number sense or number concept of small quantities. In addition, it is suggested that there is a subgroup of children who experience pure difficulties in processing magnitudes (number sense or number module deficit). Thus, because it is not clear how this deficit influences the development of verbal counting skills, the long-term predictive power of other early number skills that are easy to assess and thus could also work as early identification tools in

kindergarten should be examined in the future. For example, the long-term predictive effect of the magnitude comparison skill would be important to study. However, based on previous literature, it is expected that symbolic comparison tasks with numbers have a stronger predictive power on math skill in elementary school than comparison of quantities (Schneider et al., 2017) and thus could be assessed a bit later after children have been introduced to written number symbols. Moreover, variation in comparison speed is a main outcome variable because children typically have very high accuracy; however, measuring reaction times can cause practical administration difficulties as well when interpreting the findings in kindergarten. Thus, from a practical point of view, the long-term predictive value of other early number skills that tap the semantic meaning of number words but are more simple to assess and interpret should be explored. The number concept skill could be a potential skill because it is easy to assess, for example, by asking children to give a certain amount of items or enumerate how many objects are on a table. However, the long-term predictive power of the number concept skill and the predictive mechanism should be examined.

Another limitation of the present study is that it was not planned to analyze the extent to which the long-term predictive power of counting skills could be explained by general domain cognitive factors, such as working memory or executive functions, and to what extent predictive power can be considered to be numerical. However, it should be noted that previous studies (Koponen et al., 2013, 2016) have shown that controlling for working memory as well as language skills has not removed the relationship between counting skills and second- and third-grade arithmetical skills. Moreover, it should also be noted that the predictive power of counting skills in seventh-grade math was above and beyond arithmetical skills in fourth grade, which have been shown to be associated with early number skills, working memory, and executive functions (Raghubar, Barnes, & Hecht, 2010).

4.4. Conclusions

Previous longitudinal studies have shown that early number skills, in general, have a predictive value on math in elementary school. However, more precise knowledge about long-term predictive effects related to math performance in general as well as utility as an early risk indicator is needed to provide guidelines for early education. The present study highlights that the verbal counting skill, which is easy to assess, could be used as an early identification tool before learning written number symbols as it was shown to have a long-term predictive value on math performance in middle school and was found to work as a risk indicator. Future studies are needed in respect to other early number skills.

Funding: This work was supported by the Academy of Finland [grant numbers 63099, 778230, 292466].

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Table 1

Descriptive Statistics for Counting Skill, Control Variables, Fourth Grade Math, and Math Performance in Seventh Grade

	N	Min	Max	Mean	SD
Counting (Kg)	206	0	11	6.36	3.29
Mother's education level	183	1	4	2.67	.93
Calculation fluency (4 th Gr)	178	14	102	35.76	13.41
Procedural calculation (4 th Gr)	178	7	44	32.29	9.66
Word problem solving (4 th Gr)	178	1	20	12.02	3.37
Math performance (7 th Gr)	171	4	37	21.58	6.35

Table 2

Correlations Between Counting Skill, Mother's education, Fourth Grade Math, and Math Performance in Seventh Grade

	1.	2.	3.	4.	5.
1. Counting (Kg)	-				
2. Mother's education level	.31***				
3. Calculation fluency (4 th Gr)	.51***	.21**			
4. Procedural calculation (4 th Gr)	.54***	.42***	.55***		
5. Word problem solving (4 th Gr)	.60***	.42***	.55***	.73***	
6. Math performance (7 th Gr)	.60***	.37***	.53***	.74***	.77***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 3

Cross Tabulation of Counting Difficulties and Math Performance in Seventh Grade (Adjusted Residuals in Parentheses)

Math performance at 7th grade				
Skill level		<i>No Difficulties</i>	<i>Low</i>	<i>Poor</i>
Counting in Kindergarten	<i>No Difficulties</i>	118	13	2
		84 %	77 %	15 %
		(4.0)	(-0.1)	(-5.6)
	<i>Low</i>	16	1	1
		11 %	6 %	8 %
		(0.8)	(-0.7)	(-0.3)
	<i>Poor</i>	7	3	10
		5 %	18 %	77 %
		(-5.9)	(0.8)	(7.6)
Total		141	17	13
		100 %	100 %	100 %

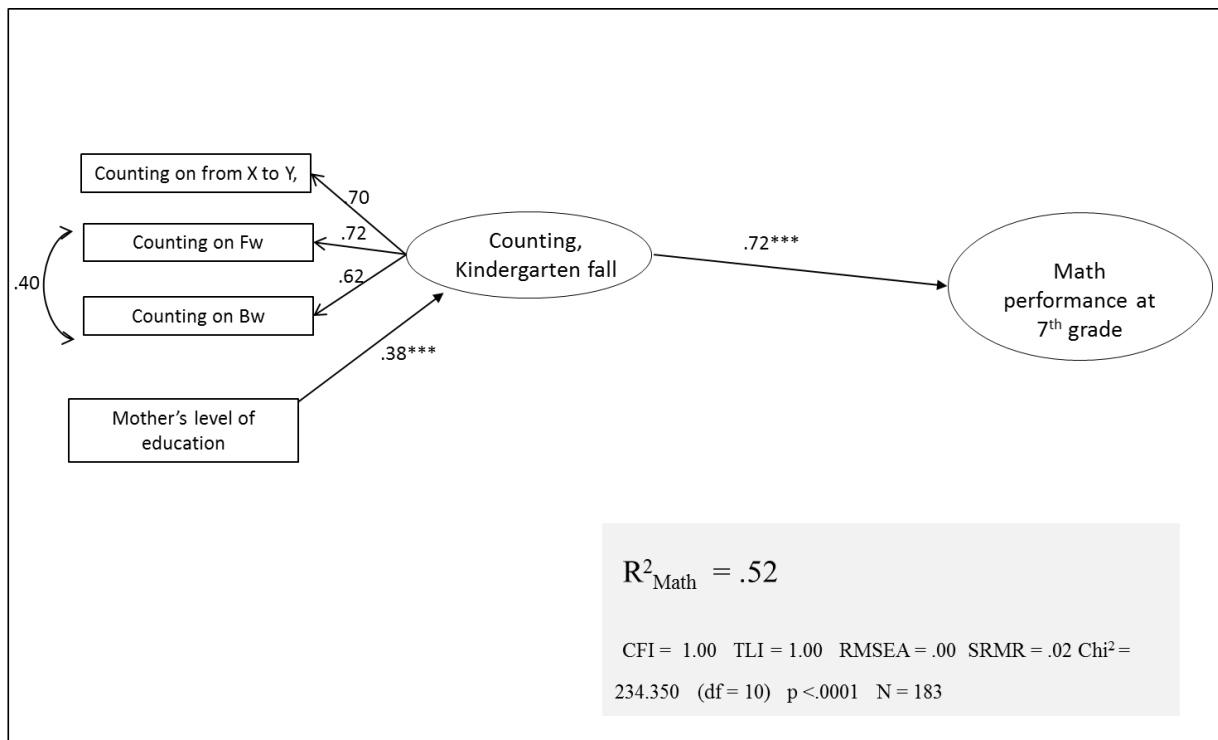


Figure 1. Counting skill, visual attention, and mother's education level as predictors of math performance in seventh grade.

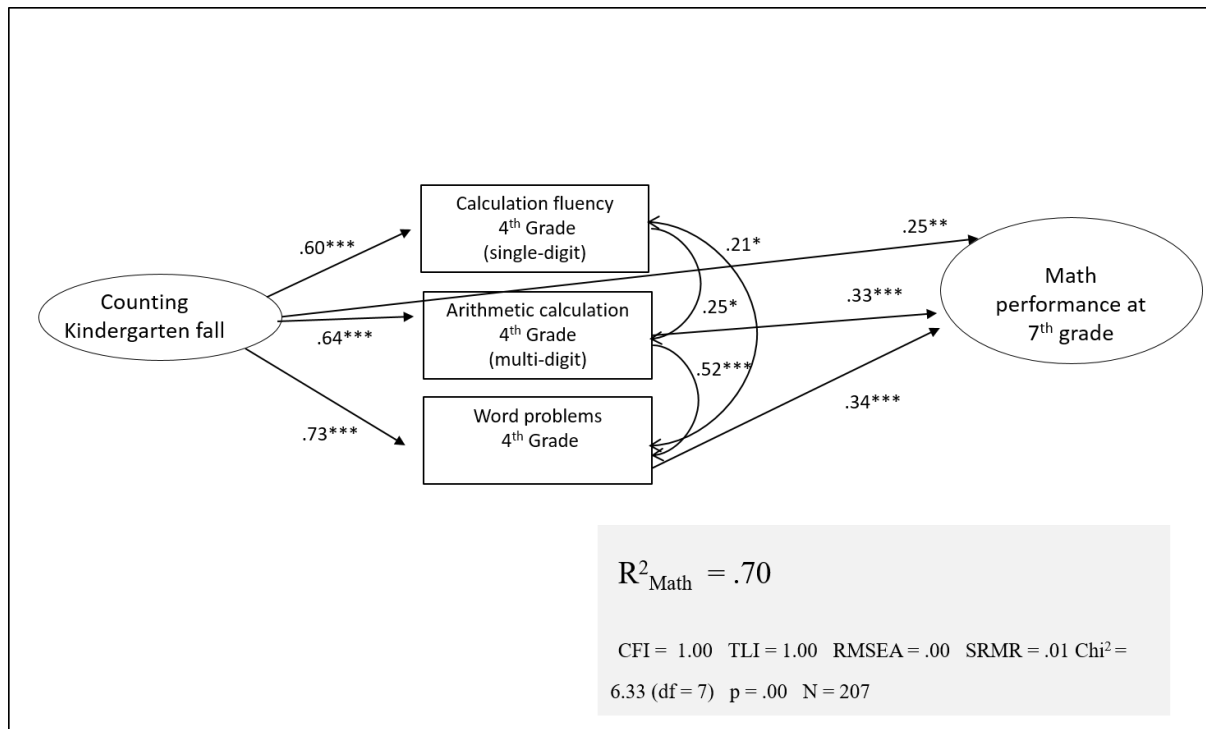


Figure 2. Counting skill in kindergarten and math skills in fourth grade as predictors of math performance in seventh grade.